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Original research article

The reality of cross-disciplinary energy research in the United Kingdom: A social science perspective

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ABSTRACT

Cross-disciplinary research is essential in understanding and reducing energy usage, however the reality of this collaboration comes with many challenges. This paper provides an insight into the integration of social science in energy research, drawing on the expertise and first hand experiences of a range of social science researchers (predominantly Early Career Researchers (ECRs)) working on UK cross-disciplinary projects in energy demand. These researchers, participants in a workshop dedicated to understanding the integration of social science in energy research, identified four groups of challenges to successful integration: Differing expectations of the role of social scientists; Working within academia; Feeling like a valued member of the team; and Communicating and comprehension between disciplines. Suggestions of how to negotiate those challenges included: Management and planning; Increasing contact; Sharing experience; and Understanding team roles. The paper offers a definition of 'success' in cross-disciplinary energy research from the perspective of social science ECRs, comprising external, internal and personal components. Using the logics of interdisciplinarity, this paper suggests that integration of the social sciences in the projects discussed may be partial at best and highlights a need to recognise the challenges ECRs face, in order to achieve full integration and equality of disciplines.

1. Introduction

Energy research needs the social sciences [42]. In a previous issue of this journal, Sovacool et al. [44] call for greater integration of the social sciences in energy research to try and overcome their current status as 'social outcast'. They suggest this should be done through: the collection of more social science data, 'problem-centred' research, and the inclusion of diverse perspectives. One example of this side-lining of the social sciences[3] is evident within energy demand research, with a study on 'smart home' technologies finding that 61% of 150 papers reviewed were led by engineering and technical sciences, with just 20% classified as social science papers [50], suggesting an imbalance in perspectives published in this area. The need to integrate the social sciences has also been recognised outside the UK (e.g. [47,49]) and is an on-going topic of debate in this journal, including discussion of how social science can and cannot contribute to climate change and energy research [34,36,22]; and the limitations associated with technical framing and bringing social sciences into projects at a later stage [28,39].

Energy demand research, which forms the empirical basis of this paper, covers areas including energy efficiency measures,

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[3] When using the term 'social sciences' this paper is referring to work conducted by sociologists, psychologists, human geographers, anthropologists, as well as those in user centred design, and in science and technology studies, amongst others. The paper chooses not to include the work of economists (which may be considered a part of social sciences) as whilst economics has much to contribute to our understanding of the human dimensions of energy, and a role to play in the integration of social science, its past dominance in energy research has been criticised and discussed at length elsewhere [18,23,36,43,45].

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behaviour change interventions, and adoption of smart energy technologies, and is an area ripe for social science contribution. More recently, opportunities for integrating the social sciences have opened up in this field, for example through the EPSRC-funded TEDDINET[4] projects in the UK, the EU Energy Efficiency Projects funded under the Horizon 2020 and COST[5] initiatives, and the USGCRP[6] in the United States. It may be said that such projects are doing what Sovacool et al. [44] suggest needs to be done in order to better integrate the social sciences into energy research. However, working across disciplines in energy research and fostering effective collaboration is not a trivial task [39] and there is a growing appetite amongst researchers of all disciplines to understand how best to facilitate this integration [26,51,10,14]. The theory of integration, and its practice in reality, are two very different things; issues which are introduced below.

1.1. Aims of the paper

This paper contributes to key debates within *Energy Research and Social Science* as it considers the ways in which the social sciences and social scientists can be better integrated into energy research [42–44]. By sharing the experiences of social science Early Career Researchers (ECRs) working on cross-disciplinary energy demand projects, it highlights the challenges to integration but also identifies the ways in which these challenges may be successfully negotiated. This cohort of researchers provides a unique perspective on the realities of integrating social sciences into energy research, given their position at the 'coalface' of research. The paper also proposes a new definition for 'success' in cross-disciplinary research, considering what this may look like and what this means for ECRs. Thus adding to an emerging literature on the reality of cross-disciplinary research, specifically from the perspective of ECR social scientists and the wider social sciences, and takes this further through a focus on the logics or ambitions driving integration of the social sciences. Whilst the paper focuses on energy demand and the views of social science ECRs in the UK, it aims for wider application, especially given that "real world problems do not come in disciplinary shaped boxes" [19]. Worldwide, government funding agencies have called for more information on interdisciplinary research; including what it is, whether their countries should invest in it, and whether it is being conducted effectively [29]. This paper thus has implications for cross-disciplinary teams, both internationally and in other fields of energy research, that bring together researchers from a range of disciplines to tackle the interaction of social and technical issues of energy production or consumption.

2. Literature review

2.1. Approaches to interdisciplinarity

Different disciplines and researchers representing them can be brought together to collaborate on projects in various ways; through 'multidisciplinarity', 'interdisciplinarity' or 'transdisciplinarity'. These forms of cross-disciplinarity may be characterised as follows: multi-disciplinarity involves putting two or more disciplinary perspectives side by side but is often seen as compartmentalised, with individual disciplines still acting alone. Interdisciplinarity indicates an attempt to integrate and synthesise the perspectives of different disciplines to provide a holistic understanding of the problem [2], though the term has become a little diluted in its application [38]. Transdisciplinarity goes beyond integration purely of academic disciplines, and involves both relevant stakeholders and the public [51]. In this paper the term 'cross-disciplinarity' has been used as an all encompassing term for these three concepts, partly because the focus of this paper is not about the terms themselves, and also because the data presented here emerged from a workshop which brought together different types of cross-disciplinarity.

In reality these forms of cross-disciplinarity represent a continuum, reflecting differences in how disciplines are brought together at various stages in the research, the power a discipline has to set the research agenda, and their control over methodologies. The social sciences have much to offer a cross-disciplinary project: unique epistemological and ontological viewpoints which can inform the focus of energy research; unique theories and ideas which can guide research questions and practices; and unique methodological approaches and tools with which to collect, analyse, and present data. Unfortunately not all of these potential social science offerings are either sought or realised in cross-disciplinary projects. Theorising the balance and equality between different disciplines integrated through cross-disciplinary research, Barry et al. [2] outline three 'logics of interdisciplinarity': 'logic of innovation', 'logic of accountability' and 'ontological logic' (Table 1). This approach helps to expose the drivers behind the integration of certain disciplines in cross-disciplinary research, and seeks to highlight imbalances in the ways in which they might be brought into and influence a piece of research. Table 1 provides an overview of the approach, including the three logics, a description of how they would be demonstrated within a cross-disciplinary collaboration, the consequence of this type of collaboration and its relevance to social science.

There is an ideal standard inferred by these logics, which suggests that only cross-disciplinary practice based on an ontological logic fully realises and captures the true potential contribution of all disciplines involved, including their philosophies, methods and modes of analysis. Integration based on a logic of innovation or logic of accountability alone only promotes *partial integration* of the social sciences.

This approach (logics of interdisciplinary), which seeks to understand and explain cross-disciplinary motivation and practice is used below to explore the reality of cross-disciplinary energy demand research in the UK. This paper does not seek to critique the approach proposed by Barry et al. [2]; rather to use the 'logics' to expose the ways in which the social sciences, and individual social scientists, are integrated into these projects. This serves to provide a more nuanced understanding of the basis on which integration occurs and whether this truly captures the full potential of the social sciences.

2.2. Integration in practice: findings and gaps

The reality of cross-disciplinary research is the focus of a variety of fields of scholarship including management studies (e.g. [17,30]), organisational studies (e.g. [37,35]) and team science (e.g. [15,27]). This paper does not aim to review that literature here, but rather highlights some key contributions which may help to understand integration within the field of energy demand research.

Discussing general cross-disciplinary research, De Boer et al. [12] (p.54) highlight several strategies to make such projects more successful: competencies of project leaders, clear working plans, communication, physical proximity, hiring at least one person with interdisciplinary experience and 'reserving separate time, manpower and funds for coordination'. Also at a generic level, Bruce et al. [8] identify key qualities that managers and researchers on interdisciplinary projects should possess, for example: curiosity, open mindedness, good communication skills and good team work

[4] TEDDINET is a UK-based EPSRC-funded network. For more information visit www.teddinet.org.
[5] European Cooperation in Science and Technology.
[6] United States Global Change Research Program.

Table 1
'Logics' of interdisciplinarity, adapted from Barry et al. [2].

Type of 'logic'	Description	Consequence for cross-disciplinary collaboration & integration	Relevance to social science
Logic of Innovation. *Also referred to by* Klein [20] *as 'instrumental interdisciplinarity'*	A discipline is brought in for its methodological contribution only.	Partial integration: The discipline's epistemological, theoretical and conceptual contributions are not recognised.	The social sciences are often used as the 'service discipline' by others, such as the physical and natural sciences.
Logic of Accountability	A discipline is brought in only to legitimise another discipline.	Partial integration: The discipline's epistemological, theoretical and conceptual contributions are not recognised.	The social sciences are often used to provide a 'protective layer' of expertise or public engagement by other disciplines ([2]; p.31)
Ontological logic Also referred to by Klein [20] as '*epistemological interdisciplinarity*'	A discipline is brought in for its ontological and epistemological contributions.	Full integration: All disciplines contribute fully and on equal standing, leaning towards the restructuring of disciplines themselves, culminating in a shared understanding.	There is a productive and equal relationship between all disciplines.

for researchers; good understanding of project disciplines and their applications, respect for other disciplines, and interpersonal skills for project leaders.

Within the field of energy demand research, an emerging literature has outlined some of the realities and challenges associated with integrating a number of disciplines, incorporating the views of a range of academics, varying in both seniority and experience (from postgraduate researchers and ECRs to professors) [26,51,10]. A recent assessment of interdisciplinarity in UK energy research identifies challenges and 'powerful transaction costs' involved [51]. Funding and policy environments are considered key to promoting success, being able to both open up, but also close down opportunities and scope for research. Winskel et al. [51] also highlight the importance of trust and familiarity amongst team members. They make a number of recommendations for researchers, funders and assessors involved in interdisciplinary energy research: valuing interdisciplinarity and individual disciplines; collaboration (e.g. with the wider research community and stakeholders); research strategy; and reflection (for instance on remit and responsibility). However, they highlight barriers that remain including epistemological and ontological divides. These findings represent a picture of energy research in the UK from across a range of fields, projects and stakeholders.

Focusing on energy demand research, Buswell et al. [10] report on the 'effort' involved in a cross-disciplinary project in terms of researchers' personal and emotional investment, and the time/cost for facilitating the research, attempting to quantify the latter through recording activities carried out and the time taken for each. They conclude by offering suggestions for how management can aid the strength of interdisciplinary insights emerging from projects involving multiple disciplines.

Considering social scientists in energy demand specifically, Mallaband and Haines [26] highlight their central role in cross-disciplinary projects, reporting that they act as a bridge not only between researchers in different disciplines but also between researchers and study participants. They suggest six principles to help guide these 'bridge builders': value others, including their work and perspectives; immerse oneself in others' work and the wider context surrounding it; communicate carefully and appropriately; translate to avoid misunderstanding; establish and maintain rapport through regular contact and meetings; and build the research and relationships iteratively throughout the lifetime of the project.

Whilst these latter two papers provide valuable insights into energy demand research, they do so from the perspective of individual projects and neither draw solely on the experience of ECRs, who are conducting research 'on the ground' on a daily basis. More focus on the ECR has been advocated, as they 'carry the main load of scientific work' while forming part of the academic precariat [24,3]. Within the field of energy demand, there is a lack of evidence from across a range of projects which draws specifically on the insights and experiences of ECRs i.e. those key elements in cross-disciplinary research. Whilst challenges to cross-disciplinary research have been identified, as have some of the solutions to these, previous literature has failed to explore explicitly what 'success' in this situation might look like. Researchers, such as Aboelela et al. [1], have identified different categories of factors for success in cross-disciplinary research, but this relates to research carried out predominantly in health and social sciences, and therefore may not be suitable within a socio-technical, energy context. Without understanding what success might look like, the goal of integration remains somewhat ambiguous.

3. Methodology

3.1. Participants

16 participants from 11 different UK institutions provided the data on which this paper is based as part of their participation in a workshop[7] organised by TEDDINET [46], which included this paper's authors. The workshop was advertised through the TEDDINET network as an event dedicated to social scientists working in the field of energy efficiency and technology.

All participants were involved in cross-disciplinary research projects on energy demand reduction in buildings. The majority were ECRs (postdoctoral researchers and doctoral students), with the exception of one professor, and a small number of more established academics. Although all participants self-identified as social scientists, a diverse range of careers and disciplines within (and beyond) social science were represented, including: human geography, economics, design, user centred design/human factors, psychology, environmental psychology, cognitive psychology, computer science, human computer interaction, ecology, marketing, civil engineering, social science, psychiatry, enterprise, and policy.

3.2. Data collection

Data were collected from two tasks that participants undertook during the workshop. In the first task, participants were sat in three small groups (4–6 people in each) and were asked to write the three biggest challenges that they personally felt face the integration of social sciences within energy research. Many participants produced more than three challenges. Each challenge was written on a separate card which were then collected, shuffled, and redistributed

[7] Held at the University of Bath on 21st and 22nd May 2015.

between the groups and participants were asked to organise them into themes. In the second task, participants were asked to list practical suggestions to negotiate these challenges, considering both social scientists as individuals and social science as a discipline within a project. In completing this task, participants were encouraged to use the challenges produced in the first task to guide, but not constrain their responses. All practical suggestions were collated and then participants were asked to each vote by marking the three items they deemed as the most important for successful integration.

3.3. Data analysis

Following the workshop, the resulting descriptions of challenges and suggestions were analysed. Thematic analysis was performed by the authors on both data sets, using the five step process outlined by Braun and Clarke [6] in which analysts: (1) familiarise themselves with the data, (2) code the data, (3) generate initial themes, (4) review themes and (5) define and name themes. An inductive approach was employed, whereby the themes that emerged during analysis were strongly linked to the data. Whilst each of the themes that were identified emerged as clear and distinct in their own right, there were also some inter-relations. To ensure the quality and consistency of the coding, the analysis was conducted by two different authors separately, any discrepancy was then resolved by discussion and the final coding was agreed upon by both authors, ensuring a rounded approach.

4. Findings and discussion

A variety of challenges to integrating social science in energy research were identified by workshop participants, as were suggestions on how to negotiate these. These challenges and suggestions are explored below in turn, followed by a discussion of 'success' in such research, from an ECR perspective.

4.1. Challenges experienced when integrating social science in cross-disciplinary energy research

Workshop participants identified 55 different challenges, which when analysed by the authors generated four high level categories: Differing expectations of social scientists, Working within academia, Feeling like a valued member of the team, and Communicating and comprehension between disciplines. Each of these categories is discussed further below.

Challenge 1: Differing expectations of the role of social scientists

Defined as: *Differing expectations regarding the role of social scientists in terms of what they can be expected to deliver and when, leading to the need for compromise.*

Nearly a third of the challenges (n = 17) related to problems surrounding differing expectations between disciplines. In many cases these expectations were largely related to job roles, for example, a '*lack of understanding of what social science is*' and therefore confusion surrounding what social scientists will bring to the project or the knowledge and skills they have, as demonstrated by the following quotes:

> *'The assumption that I will understand high level engineering because the others do*'

> '*Your job is to ensure people engage with our not-as-yet-ready, half-baked, scary-looking "thingamajig" aka managing the engineer's expectations*'

The integration of the social sciences described here is used as a superficial or 'protective layer of expertise' (i.e. logic of accountability, [2]), as social scientists were given the role of ensuring the public engaged with the energy technologies developed by engineers in the team. The inclusion of the social sciences to legitimise and reduce controversy over projects' social outcomes has also been noted in other situations [49]. Such an approach risks side-lining the theoretical and conceptual insights of the social sciences. Misunderstanding surrounding the input of social scientists, as highlighted here, suggests that the full range of contributions from the social sciences is not recognised, and social scientists may feel outcast if a logic of accountability is adopted from the outset, thereby failing to demonstrate equality between the disciplines (see Section 2.1).

Several participants described the common misconception amongst their project teams that those employed in a *social science* role should have responsibility for any tasks relating in any way to people. In some cases participants reported being assigned administration tasks (for example, stuffing envelopes) more frequently than those with an engineering specialism, as demonstrated by the following comments:

> *'Being the general person for anything to do with people'*

> *'Having to do ANYTHING related in ANY way to people!. . ..Jack-of-all-trades'.*

The examples given by participants indicate a tendency for social science to be used as a 'service discipline' (i.e. logic of Innovation [2]), where the social scientists are included for the 'services' they can provide, i.e. their ability to deal with any duties or tasks relating to people. Again, this fails to recognise the discipline for its full range of potential contributions and does not demonstrate interdisciplinarity based on an ontological logic.

There was also discussion around encountering the traditions of different disciplines, where disciplinary collaborations have to contend with different or even opposing methodologies, epistemological stances, theories, hierarchies or power relations. As discussed above, the examples given by participants of cross-disciplinary working evidence that in many cases, the input of the social sciences is limited to methodological contribution or to serve as a 'protective layer' (i.e. logic of innovation or accountability [2]. By its nature, this means that the wider contributions of the social science are not recognised.

Participants also discussed differing expectations relating to timescales and processes amongst different disciplines, as also highlighted by Buswell et al. [10] in their quantification of the operational effort to complete the LEEDR project. In part these differing expectations stem from working within academia, as university structure dictates the rules and regulations applicable to each department or discipline. For example, whereas engineers may simply trial a prototype in a laboratory to secure proof of concept, social scientists need to acquire ethical approval from a university board before conducting randomised control trials with multiple households, highlighting not only a more convoluted process, but also the associated time demands.

Challenge 2: Working within academia

Defined as: Academia comes with its own structure, ethos, and culture and working within these parameters emerged as a challenge. All common elements of working within academia, regardless of the field were included, such as processes within individual Universities particular to academia and wider issues relating to governing/funding bodies.

Nearly one-third of the challenges (n = 15) discussed related to the rigidity, complexity, and institutionalised nature of working within academic institutions. Some of the challenges relating to publishing, for example, the difficulty in finding an outlet for interdisciplinary papers deemed acceptable to multiple disciplines

as well as their own discipline (a concern raised elsewhere, e.g. [11,51]). As demonstrated by the following quotes, there were minimum standards of journals within different disciplines and the type of publications that would be acknowledged by the Research Excellence Framework (REF) in the UK within one's own department [33]:

'Impact factors – [we were] given a number not to go below by another discipline'

'Publications that are acknowledged as "REFable" within my own department'

Other challenges regarded funding, where a lack of understanding from public funding bodies about the time and effort required to conduct social science research as part of technical projects was suggested, leading to unsuccessful funding applications, as intimated by the following quote:

'Funding bodies don't appreciate what it takes to 'do' social science'.

Concerns exist over the ability of the current UK funding system to fairly assess interdisciplinary applications due to the difficulty in obtaining high quality peer reviewers [31], a concern which has also been echoed for the US [11]. Similarly, the seeming lack of understanding from policy makers was also discussed, particularly in relation to results from projects:

'Getting social science to be taken seriously and considered within 'evidence' based policy making'.

Other challenges arose through the perceived 'abandonment' of academics who were not practising in a pure social science area or the discipline in which they had trained. These participants felt that they lacked institutional support (e.g. administration, IT, funding, peer research group) as they fell between disciplines or departmental responsibilities (also noted by [3]). The following quote, and specifically the emotive wording used, is suggestive of the sensitivity surrounding this topic:

'*I'm a social scientist too! Staying relevant to your discipline [is the challenge], and not be [seen as] the one who sold their soul*'.

In addition, participants also noted that the framework of specific institutions can limit and constrain the social science input:

'Institutional processes and culture 'framing' the input of Social Scientists'

Winskel et al. [51] also note the importance of academic working practices and cultures on conditioning opportunities for cross-disciplinary research. These structural issues are not restricted to energy research [8] and will be slow to change.

Challenge 3: Feeling like a valued member of the team

Defined as: *The extent to which participants perceived that their contributions to the team as social scientists were valued, both by others and also by themselves.*

Just over one fifth of the challenges (n = 12) identified were related to value and recognition in cross-disciplinary teams. These challenges involved a critical assessment of the contributions that social science can bring to a project in terms of the methods used, credibility of the data and conclusions, and the 'real world' impact. This was particularly evident in the choice of words and phrases participants used, e.g. '*Legitimacy*', '*evidencing our relevance*', and '*demonstrating the value*'. Participants suggested that there is often a misguided perception from other disciplines that they '*already "know" what people think/do*' and therefore they do not value the need for social or other 'soft' sciences. The social sciences therefore face a contradictory challenge, when non-social scientists within the team claim the ability to 'speak human' [41], and thus call into question the disciplinary expertise and skills of the social scientists.

Interestingly, there was some indication that participants felt the need to justify their contributions not only to '*other disciplines*' but also to themselves as demonstrated by the following quotes:

'When the conclusions are essentially "people are complicated" it can be difficult to justify the research programme'

'So what? What does the work mean and how does it benefit those participating?'.

Such comments suggest there may be a cyclical relationship between external and internal value and recognition; it appears that justification of value and approaches used by social scientists to other disciplines can then prompt critical appraisal of their own contributions. It is suggested that if integration of the social sciences occurred based on an ontological logic, then a more complete understanding of the value of social scientists amongst other team members would ensue, and social scientists would not need to justify their own worth and value to themselves. Promoting this level of integration would involve clear communication and comprehension of each other's disciplines, although this in itself is a challenge.

Challenge 4: Communicating and comprehension between disciplines

Defined as: *The difficulties encountered in speaking with and understanding other disciplines within the project team.*

One-fifth of the challenges (n = 11) related to difficulties in communication and comprehension between social scientists and other disciplines. These ranged from the differing meanings of words between the disciplines and difficulty finding a 'common language', to the uncertainty of social scientists about how to converse with other disciplines, particularly around complicated technicalities as demonstrated by the following quote:

'[The challenge is] communicating with non-social scientists, without sounding stupid!'

Participants recognised the need for comprehension in terms of being able to understand each team member's responsibilities (see also Challenge 1: Differing expectations of social scientists) and to acquire knowledge of the other disciplines and the ways in which each part of the project fits together. However it was acknowledged that perhaps more time was needed for this than was available to project members, as also suggested by Winskel et al. [51] and De Boer et al. [12].

Whilst it is clear that comprehension of other subject areas can be a challenge (e.g., '*understanding and being able to explain "system architecture"*'), good communication and appropriate time allowance is key to this. Misunderstandings due to poor communications and comprehension can be particularly damaging at the project level, as they limit the potential for shared understanding to arise and for innovative outcomes to emerge.

4.2. Negotiating the challenges

Following the identification of challenges experienced in cross-disciplinary projects, participants were encouraged to recommend practical suggestions to help address these challenges. There were 28 suggestions made, which following analysis by the authors, were grouped into four high level categories: Management and Planning; Increasing contact; Sharing experience; and Understanding team roles.

Suggestion 1: Management and planning

Defined as: *Ensuring that the tasks that need to be accomplished in order to meet the project's objectives are appropriately managed and planned.*

Almost one-third of suggestions (n = 9) relate to management and planning, and over 50% of participants voted this category as the most important for ensuring success in cross-disciplinary projects.

Participants discussed the need for specific project management, either by an external project manager, a dedicated project management work package or the Principal Investigator (PI). It should be noted that a dedicated work package may not be possible in smaller projects, but in practice some European projects (including Horizon 2020) require this to be included in bids. Participants also suggested the need for the PI to have training for managing a cross-disciplinary project and specifically, sociotechnical projects. It was recognised that not only do academics rarely have management training, but they have their own specific field of study and therefore the misconceptions and traditions that might accompany it.

Participants also discussed the need for appropriate and flexible planning. This included the need to plan the end of the project to ensure appropriate closure of activities and dissemination, allowing for likely slippage, as demonstrated by the following quote:

> *'Plan a softer ending – [the] opposite of a messy ending (slippage etc.). Plan a 'tapering off' window'*

This type of slippage is possible in any research project, but the risk could be greater in cross-disciplinary projects where time is needed to understand the work required from other disciplines, and to manage the differing timeframes and end points related to each discipline involved.

Effective planning is needed as projects come towards an end, particularly in academia where the majority of UK research staff are on fixed term contracts [9] and thus may leave the projects before its completion. The need for classification and description of project roles was also highlighted, where boundaries between disciplines and specific responsibilities are discussed and agreed. Ideally this would be fed down from the project management, however, it is acknowledged that this is likely to change as the project progresses and should be an iterative process.

In order to promote successful working, the project PI must pay attention not only to disciplinary excellence and scientific rigour throughout the team, but also to personal and professional relationships between team members. PIs are generally self-selecting and funding is awarded to them based on disciplinary expertise and past project performance, not on their ability to manage people or build productive relationships (although project performance may in part reflect this). Recognising that these can be difficult skills to acquire, workshop participants suggested that PIs be supported in this, either through direct training or in the form of staff dedicated to cross-disciplinary project management (echoing a suggestion made by [51]). Universities and funding bodies have a role to play here in promoting the need for and supporting the cost of training.

Effective management and planning (suggestion 1) can be crucial in creating the conditions for team contact (suggestion 2), sharing of experiences (suggestion 3), and understanding roles within the team (suggestion 4) and was identified by participants as the most important group of suggestions in ensuring success in cross-disciplinary projects.

Suggestion 2: Increasing contact

Defined as: *Spending time with other team members both formally and informally throughout the duration of the project.*

Just over one-fifth of suggestions (n = 6) related to increasing contact and communication within the project. Participants specifically discussed the potential of having informal, social events as a project team, particularly at the start of the project. It was suggested that not only does this help to build relationships within the project, whilst removing the tension of work related conversations, but also allows project team members to learn more about each other and differing communication styles from an early stage. This space could be kept for purely non-work discussion, or could be used to informally discuss past project experiences; one participant commented:

> *'When we met for a meal as a project team, I discovered that two other team members were keen photographers which automatically gave us something to bond over and discuss, which lessened the pressure of only ever talking about work'.*

Fong [13] relates this to 'boundary crossing' between team members of different disciplines. This allows team members to find connections, which might be personal; ideally the PI will provide an example of such connections, which can be followed by the rest of the team. A number of participants discussed having trialled a communal office location for project members of different disciplines. This was regarded with varying levels of success, but for some was felt to be a positive step for a project team, particularly in the early stages. Where this is not feasible, participants suggested that at the very least there is frequent contact between project workers, ideally face to face, but using online tools if necessary e.g. Skype. One participant mentioned how important discussion is for compromise and establishing '*trade-offs between disciplinary needs*', specifying that not only is frequent contact necessary but that '*Projects need to allocate time for continual discussion*', which is obviously made easier by a shared location.

Whilst willingness to participate in frequent, informal social events is necessary by the whole project team, facilitation of these events is likely to need to come from project management, particularly in the first instances before relationships are formed. The provision of a communal office location for project members of different disciplines and departments would need to ultimately be provided by the University estates team, however, this would need to be requested by project management. The whole team would need to allocate time in their schedules for continual discussion.

Contact can be promoted through project PIs ensuring and facilitating shared office space for researchers, regular team meetings, and informal gatherings. This alone however is not enough to ensure mutual understanding and respect for one's colleagues. Indeed, several workshop participants shared stories of arguments within team meetings or conversations, indicating that a solution needs to go beyond merely facilitating face to face contact, to include mutual respect as well.

Facilitators or translators may be used to aid communication between those from different disciplines, and thus increase understanding amongst team members and ensure each values the contributions of others. This however, requires extra time, as well as individuals who are willing to act as translators and facilitators [26,25,51]. These translator roles often fall to social scientists given their professional concern with people; however this places the burden of responsibility on one (or a few) people rather than the team as a whole and fails to account for personality, likeability or aptitude in translation of information or facilitation. It may be that formal facilitators or mediators can instead be used, possibly at different points throughout a project.

Expectations on the level of cross-disciplinary working desired may differ between different work packages within the same project, highlighting the need for regular contact and communication throughout the project [26].

Suggestion 3: Sharing experience

Defined as: *Discussing with others the actual lived experiences and lessons of working on a cross-disciplinary project.*

Just over one-fifth of suggestions (n = 6) discussed the need for more sharing of current and past experience both between other academics working on the same project and those on other related cross-disciplinary projects. They mentioned frustrations on how

particular information, such as discussion of methods, was often removed from publications even though it may have proved valuable to the reader These differing expectations of publication relate to challenge 1. It is important that both successful and less successful methods are recorded in the literature to document how practice has progressed.

Participants highlighted the benefit of contributing to networking events, conferences and publications throughout the project, rather than merely at the end. Whilst it was acknowledged that this can be difficult due to time constraints whilst the research is being carried out, there was often inadequate time at the end of projects for sufficient publication, particularly when researchers on fixed term contracts were preparing for/seeking their next role. Participants also learned from others' experiences through shadowing other academic staff as well as through peer support. For example, the UK EPSRC[8] funded the TEDDINET network (with the aim of bringing together multiple cross-disciplinary energy demand research projects), and was highlighted by workshop participants as a good example, given it creates opportunity for sharing experiences which benefit both the individual researcher and the research project:

'It has really meant a lot to me to meet people at the same career stage who 'get' the highs and lows of our job'.

Such positive feedback indicates the value of collaborative networks, as it is evident that researchers appreciated not only the opportunity to network and share information across similar projects, but also to access peer support. Such network collaborations can be supported by both universities and funders, and are valued not only by ECRs but also by senior academics, funding institutions, policy-makers and those in industry [48]. Others echo these calls for increased collaboration amongst the wider energy research community [51]. The task of sharing information etc. through networking events is the responsibility of all members of the research team, to be willing to present and prepare information, but the project management team is able to facilitate this more easily through allowing flexibility in working practices and releasing funds for networking and conference attendance.

Participants also discussed the need to provide support and feedback within their project team, however that feedback should be '*mediated and managed*' to ensure that the outcomes were positive both to individuals and for the project. One suggestion of how this sharing could occur within and outside the team was that *"Different members of [the] team [could be] asked to blog regularly"*. As an example, these blog posts could include project updates, thoughts and experiences, findings, developments, reviews of literature etc. This could be included as part of project members' job descriptions and could contribute to the project's pathways to impact agenda, in particular through encouraging public engagement with the research. In addition, restricted access blog posts could be used to communicate solely within the project team. The responsibility of sharing information via online blog posts would need to be agreed to by project management, but it would be expected that much of the blogging would be carried out by the researchers. Support and provision of an online platform could also be facilitated by the wider University.

Suggestion 4: Understanding team roles

Defined as: *Ensuring team members have a knowledge of each other's roles and the duties they can be expected to perform within this capacity.*

Just under one-fifth of suggestions from participants (n = 5) discussed the need to understand the differing roles within a project team. In contrast to suggestion 1: Management and Planning, this suggestion is the responsibility of both the individual researcher and the whole team, as opposed to solely managers. Participants suggested a number of ways this could be achieved, but highlighted that this required effort from the individual, particularly as part of a continual process. It was suggested that projects need to address this at an early stage to identify the different skill sets within the team and to identify who can facilitate the interaction of different disciplines, as demonstrated by the following quotes:

'Recognise the need for someone to facilitate between disciplines, projects identify who will do this and allocate time for shared learning.'

'Checklist at the start of contract: to raise awareness of other disciplines and agreeing to show respect to disciplines, seniority, gender, age'.

While the latter quote most likely refers to an informally agreed set of 'ground rules' for team working, in some cases, participants suggested using a formal approach such as using a skills analysis tool (e.g., Belbin® [4,5]) to identify differing skills within the team, while others took the opposite tact *of 'loosening (individual) identities'* in order to build a more common identity. The use of an analysis tool for identifying different team skills and personalities is seen to lie with the Project PI or Co-I, although in some cases, personal development sessions in this area may also be made possible by University-wide provision. Likewise, whilst the project management team should promote facilitation between disciplines, the University may provide trained individuals in facilitation to assist, or provide support in this instance.

4.3. What counts as 'success' in cross-disciplinary research?

In order to consider the challenges to cross-disciplinary research and the suggested ways in which these can be negotiated, it is necessary to think about what 'success' looks like in this context. Aboelela et al. [1], focusing mainly in the health and social sciences domain, identified from a literature review that there were a number of categories of factors which were important to the success of cross-disciplinary research: environmental/institutional factors, team factors, or individual characteristics of team members. The research discussed in this paper builds on this research using first hand experience of ECRs working within energy demand research and through analysis of participant data, a definition of success from an ECR social science perspective can be divided into *external, internal* and *personal* success. Whilst previous literature has discussed the notion of external success, the idea that both internal, external and personal measures of success must be met is novel and necessary for the researchers working 'on the ground'.

External success is shown by a project whose results are presented in both academic and non-academic circles, which can be discussed in plain language and which not only has the opportunity for real-world impact and change, but can also inform research practice and methodology.

Internal project success is denoted by a team where all members feel valued, respected and equal with a shared understanding of what each other are doing and who work towards integrated results, with common agreed-upon project goals.

Personal success is demonstrated by researchers with opportunities for medium and long term career development, skills acquisition, feeling valued and a good work-life balance.

Fig. 1, below, depicts how the three different elements of success interact. It also depicts how different stakeholders in the cross-disciplinary research process, namely; universities, funding bodies, project PI's, members of the project team and the individual ECR have an involvement with the different elements of success.

[8] Engineering and Physical Science Research Council.

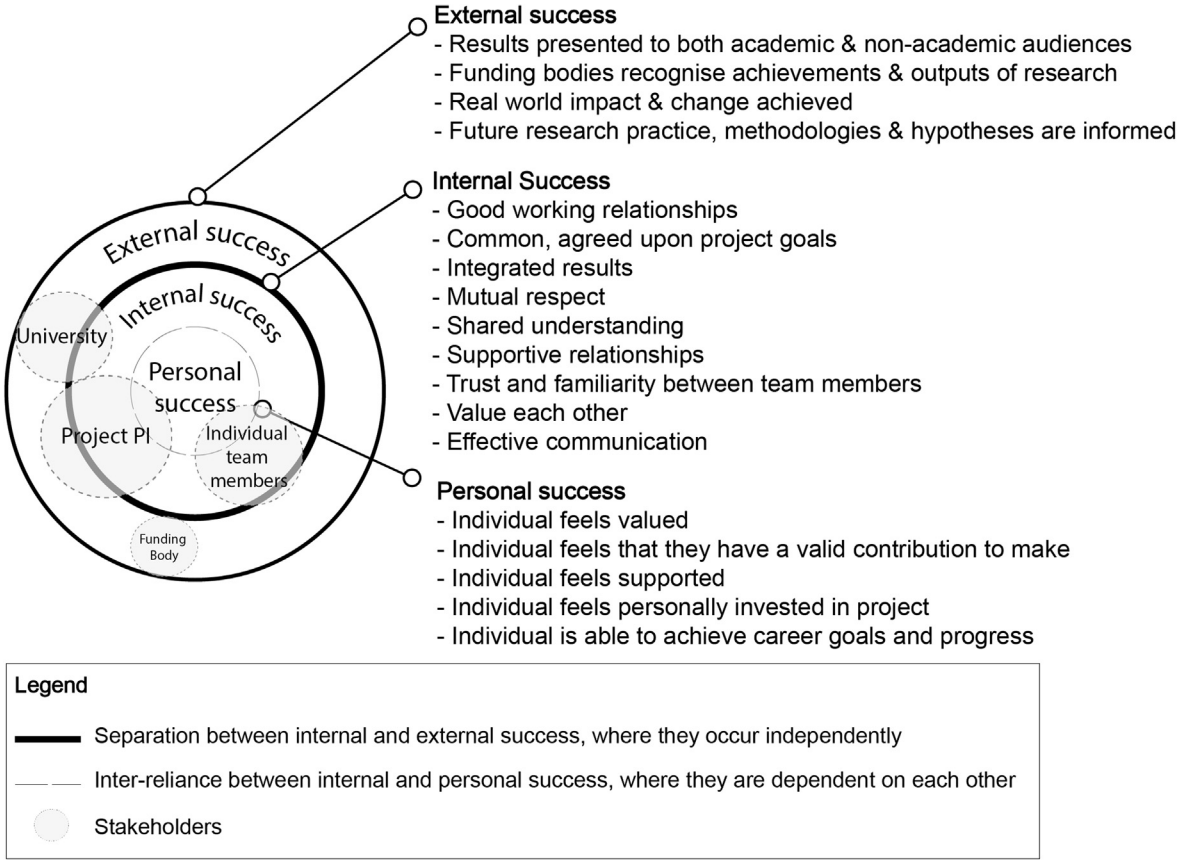

Fig. 1. How do the three elements of success interact?

The figure indicates that funding bodies are predominantly a stakeholder in external success, whilst universities also have some effect on internal success. The project PI is likely to be a stakeholder in all three elements and individual team members most likely predominantly internal and personal. This corresponds with the results discussed in this paper, where participants clearly indicated that project management and other team members have a significant role to play in negotiating cross-disciplinary working challenges.

The diagram also indicates that whilst in theory, internal and external success can occur independently (indicated by a thick, solid line), in order for a project to be truly 'successful', all three measures need to be met. The diagram also depicts that internal and personal success are significantly linked (no solid line between them) as it is highly unlikely that personal success could exist without internal success and vice versa, e.g. where supportive relationships and mutual team respect etc. will help the individual researcher to feel supported, valued and respected (as shown by [16]). Whilst team members may have a common project goal, each member's definition of success may vary according to their disciplinary perspective [21] therefore it is important that project objectives are agreed upon between team members, with each team member relating how success looks for them.

Winskel et al. [51] call on UK energy research projects to be more explicit in their interdisciplinary ambitions. This paper echoes this call but also urges them to strive in their integration for all three elements of success as outlined above. A key remaining challenge is how to measure this success, as that will depend on which perspective is taken and it may only be obvious in the medium to longer term. Adopting Barry et al.'s [2] logics of interdisciplinarity (Table 1), there is evidence in the findings presented here that the social sciences are integrated into energy research based on a limited input, for example their methodological approaches (logic of innovation) or superficial legitimising expertise (logic of accountability), yet there is no evidence that they are fully and equally integrated (ontological logic). This may be taken to suggest that the integration of the social sciences in some UK energy demand projects may at best be partial, as the conceptual and theoretical offerings of the social sciences may not be fully realised in the research process. An alternative explanation of the situation is that integration based on an ontological logic *does* exist yet simply goes unmentioned in the participants experiences shared here as they focus on the challenges to integration, not what works well. However, the challenges identified, particularly around differing expectations of roles (challenge 1), feeling valued within the team (challenge 3), and challenges of communication and comprehension (challenge 4), warn against this interpretation. They suggest that more needs to be done to fully grasp and comprehend the entire range of contributions of each discipline within the team so that all team members feel their roles are fully valued. This paper recommends that adopting the suggestions put forward may go some way to increasing mutual comprehension and respect in cross-disciplinary energy research, and thus promote a more complete integration of all the disciplines involved, including the social sciences.

It is suggested that research which strives for external, internal and personal success (as defined above) will tend towards full cross-disciplinarity based on an ontological logic, given these successes can only come about through complete integration of all disciplines. Complete integration would encompass all that a discipline has to offer, rather than only a limited subset, such as methodological approaches and tools.

4.4. The reality of cross-disciplinary energy research for the social science ECR

As discussed, many of the challenges outlined in this paper have significant consequences at an individual level for researchers working within cross-disciplinary teams, and for ECRs specifically. As the majority of ECRs in the UK are on short-term contracts, they are under considerable pressure to ensure they perform well to maximize their future employment prospects [9,40].

Cross-disciplinary work is resource intensive, requiring extra time and effort to ensure that the project progresses [51]. Although cross-disciplinary collaboration is increasingly called for (e.g., [29]), it does still not seem to be widely championed (see challenge 3). In many cases the hallmark of academia is deemed to be shown by success in a single discipline (see challenge 2) and often by individual academics, yet disappointingly, workshop participants reported needing to be 'Jack-of-all trades' (see challenge 1). For example, many lectureships require mono-disciplinary expertise, and the majority of universities, journals, research councils, and professional societies continue to operate using single disciplines [31]. Thus ECRs must balance the demands of cross-disciplinarity against the demands of acquiring the specific mono-disciplinary credentials that are often needed to obtain a first lectureship. In theory, producing cross-disciplinary research should not count against an ECR looking to advance their career due to the REF [33] explicitly stating that interdisciplinary research should be treated equitably, however, in practice, departments often fail to implement these guidelines.

Therefore, whilst current academic working practices (challenge 2) create little incentive, particularly for ECRs, to work across disciplines, the movement towards becoming an 'interdisciplinarian' may be positive for some researchers who embrace and pioneer this unique identity. It is expected that more senior social scientists; e.g. those working as project PIs or Co-Is, experience less pressure to compromise their disciplinary expertise given their status as permanent employees and their substantial research portfolios. Winskel et al. [51] allude to transaction costs involved in cross-disciplinary research and it is suggested that these are felt particularly by ECRs.

Despite the challenges experienced by ECRs on an individual level, their role in the promotion of successful cross-disciplinary research is an important one. Being in regular contact with colleagues (suggestion 2), sharing experiences with those outside the project team (suggestion 3) and understanding the roles of all those within their team (suggestion 4) all depend on the willingness and commitment of individual researchers within the team. Spending time together, either formally or informally (e.g. through team meetings or shared office space or communal space) enables communication and builds rapport and tacit understanding within the team [26,25,10]. This can be particularly important in cross-disciplinary teams, where different disciplinary cultures may magnify the divergent expectations and perceptions of success that are situated within disciplines [32]. Again, it is suggested that agreement of project goals may be particularly relevant for those employed as postdoctoral researchers on projects as they are heavily invested in the research and depend directly on the connections to their early-career colleagues from other disciplines in order to complete their own work. The 'relational capital' [32] built through these 'mundane interactions' [49], whilst important in cross-disciplinarity, will reflect the outlook and enthusiasm of the individual ECRs involved and as such cannot be guaranteed. Therefore, responsibility for promoting, enabling and inspiring the building of relational capital also lies at the research team level.

Whilst the role of the ECR is clearly important for conducting successful cross-disciplinary research, it is also likely that these researchers will have developed skills which provide them with better job prospects both inside and outside of academia, by fostering cross-disciplinary thinking, being exposed to people from different disciplines and thus increasing their potential to secure funding [7].

Strategies to improve team contact (suggestion 2), share experiences beyond the team (suggestion 3), and work towards a better understanding of team roles (suggestion 4) should thus be organised and coordinated at the project or research team level, with a view to improving the overall quality and insights of the research conducted. Ultimately, effective management and planning (suggestion 1), often above the level of the individual ECR, is necessary for this to occur.

5. Conclusions

Whilst there is an increasing recognition that social science must be incorporated into energy related research so that social scientists are no longer 'social outcasts' [42], there are still few energy demand research papers and projects led by social scientists [50]. Opportunities for cross-disciplinary research are emerging but there remains a lack of understanding as to how to integrate social science and social scientists in practice or the consequences of this integration (or lack thereof). This is key from the perspective of ECRs, who are the doing the research 'on the ground' and interacting on a daily basis with colleagues of different disciplines. This paper suggests that there is a need to recognise the challenges ECRs face, in order to achieve full integration of disciplines, whereas other studies have focused more on more senior and experienced academics.

By sharing experiences of social science ECRs working on cross-disciplinary energy projects, this paper highlights the challenges they face and suggests ways of negotiating them. A report written from a senior researcher perspective mentions communication and difficulty in bridging between disciplines as the most prevalent challenge [12], whereas the findings reported here highlight the differing expectations of the role of social scientists in cross-disciplinary teams as the most frequently suggested challenge. As well as effective management and planning (voted as the most important suggestion for successful cross-disciplinary projects), participants discussed the usefulness of sharing their experience within and between project teams. Whilst this is likely to be more beneficial for ECRs, it is suggested that sharing between more senior project members, which may be facilitated through networks like TEDDINET, would also be beneficial.

This paper also offers a definition of what success looks like on an external, internal and personal basis, from an ECR perspective, taking into account an individual's perceptions and experiences within the project, rather than merely the project's and wider University's research agenda. It is clear from the experience of participants represented in this paper that projects can have external success, without internal or personal success, but this is likely to be to the detriment of the ECR. Additionally, research projects are not conducted in a vacuum and institutional and financial support are also key to successful cross-disciplinary research.

Although differing funding and policy environments create country-specific contexts for cross-disciplinary energy working [23], the findings presented here have significance for all those engaged in cross-disciplinary energy research, both in the UK and beyond. Future work would benefit from discussion with career interdisciplinarians who may offer other productive ways of bridging the gap between researchers who use different methodologies, as well as with social scientists working outside of the UK, to identify similarities and differences in their experiences. The preliminary stage of this research was to focus purely on the views of social scientists, however, further study could also ascertain the views of other disciplines who work with social scientists. Oppor-

tunities also exist to explore the consequences of cross-disciplinary work which is deemed successful (or not), and how to assess that success.

Whilst current academic working practices will no doubt remain a significant barrier to effective cross-disciplinarity in the future, there is much that can be done now to build relational capital amongst team members and thus increase the possibility of a shared and holistic understanding emerging from cross-disciplinary energy research.

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